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SURFACE SLICKS AND NEAR-SURFACE VARIABILITY: A LITERATURE REVIEW AND SOME MEASUREMENTS IN THE GULF OF CADIZ

by

BRIAN WANNAMAKER

15 JANUARY 1980

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SACLANT ASW Research Centre
Viale San Bartolomeo 400, I-19026 San Bartolomeo (SP), Italy.

tel: national 0187 503540
international + 39 187 503540

telex: 271148 SACENT I

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SURFACE SLICKS AND NEAR-SURFACE VARIABILITY: A LITERATURE REVIEW AND SOME MEASUREMENTS IN THE GULF OF CADIZ

by

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Brian Wannamaker

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This memorandum has been prepared within the SACLANTCEN Underwater Research Division as part of Project 01.

G.C. VETTORI
Division Chief

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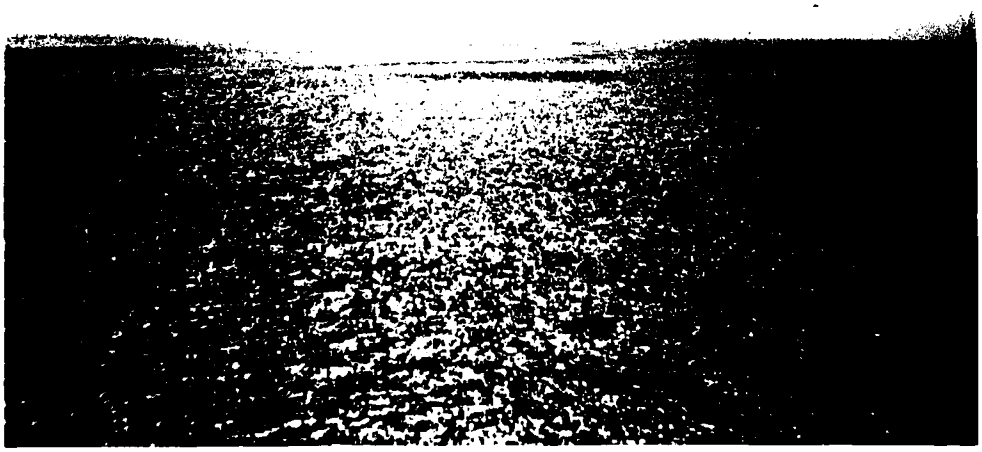

FIG. 2 SLICKS SHOWING AS DARKER GREY IN THE SUNGLINT PATTERN

SURFACE SLICKS AND NEAR-SURFACE VARIABILITY: A LITERATURE REVIEW AND SOME MEASUREMENTS IN THE GULF OF CADIZ

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ABSTRACT

Bands of smooth water, or 'Slicks' commonly occur on the sea surface. The size scale and orientation of arrays of slicks may be indicative of subsurface flows due to internal waves, Langmuir circulation, or fronts. Under summer conditions in the Gulf of Cadiz the sea temperature has been observed to exhibit sudden negative temperature spikes of 1.4° C at 4m depth on size scales of slicks. Slicks may indicate conditions of variability in air/sea interaction processes and near-surface sound transmission.

INTRODUCTION

On 26 and 27 June 1978 the SACLANTCEN research vessel MARIA PAOLINA G. was involved in an XBT and near-surface temperature survey in the Gulf of Cadiz. Under calm sunny conditions on the second day a number of bands of smooth water, or slicks, were noted visually. Significant variation in the temperature of the sea was observed on the same scale. This paper is a literature survey and analysis of the data that was undertaken to study this unexpected phenomena.

1 LITERATURE REVIEW

Common features of the surface of large bodies of water are regions or bands of calm water or slicks (Fig. 1). For an observer near the sea surface, and with the sun well above the horizon, the slicks appear lighter than the surrounding water. Near sunrise or sunset in the sun-glitter pattern, the slicks appear darker than their glittering surroundings (Fig. 2). In both cases the slicks are noticeable because of the damping effect of the slick material on capillary waves, which in turn affects the amount of light reflected to the observer. Slicks are now usually associated in the public mind with petroluem products but may be due to purely biological processes and independent of human intervention. They may exist in any region of sufficient animal productivity <1>.

Naturally-occurring slicks are the result of the compaction of minute amounts of surface-active substances or surfactants in a monomolecular

layer. These are classed as "dry" or "wet" depending on the proportion of the individual molecules below the water surface. Dry surfactants refer to oily or fatty molecules, of which most of the hydrocarbon chain is above the surface. The lower end is held in the water by an electrical bond. Generally more abundant on the ocean are wet surfactants, typically proteins or glycoproteins, with most of the molecule submerged. They are attached to the surface by occasional hydrophobic side chains <2>. Gas bubbles in the sea collect the active material in subsurface waters and transport it to the surface.

The returning portion of nocturnal thermal convection cells is another upward transport mechanism. Under severe wave conditions the surfactants are submerged by turbulent overturning or ejected into the marine atmosphere by bursting bubbles <3>.

Although surface-film material is generally existent, at least in regions of biological activity, slicks become visible only when the surfactants are forced into a close-packed grouping. In this condition the surface tension is reduced sufficiently that capillary waves do not form. If the compaction exceeds this, the film folds and masses into a foam <1>.

In favourable conditions, patterns of slicks are indicative of surface and subsurface flows. The most notable of these are Langmuir circulations and internal waves. Dampening of waves in these slick patterns may be reinforced by masses of algae or seaweed also collected by the water flow patterns <4>. Lines of foam are often associated with regions of strong vertical flows at density fronts <5>.

Under wind speeds greater than 3 to 4 m/s, visible slicks tend to quickly (10 to 20 min) line up to within a few degrees of the direction of the wind in parallel arrays separated by rougher patches about five times wider than the slicks. This pattern is indicative of the near-surface circulation pattern first described by Langmuir in his classic 1938 paper <6>. Through some disputed process or set of processes, air/sea interaction sets up a set of helical motions in the upper layers of the sea <7>. Recent theories favour an interaction mechanism between surface waves and surface currents <19, 20>.

The slicks overlie regions of concentrated down-welling; between the slicks are areas of more diffuse up-welling. The surface current is directed in towards the slicks and there is a strong (approx. 10 cm/s) component in the wind direction along the slick. The row spacing may be 2 to 25 m in lakes and 2 to 300 m in the ocean. Langmuir circulations are a strong factor in transporting momentum into the water and in the deepening of the mixed layer <8>.

In a continuously stratified ocean, internal waves exhibit a continuous spectrum. However, on a continental shelf under strong seasonal stratification conditions the ocean may be approximated by a two-layer system separated by a sharp pycnocline. Internal waves seem to occur in packets of less than ten wavelengths and, if the amplitudes of the waves are greater than about 1/4 of the depth of the mixed layer, the orbital motion

associated with the wave will cause sufficient expansion and contraction of the surfactants to induce slicks on a relatively calm sea surface. They will form over the down-welling water behind the crest of the internal wave <1, 9>.

If the resulting slicks are on a large enough scale they can be seen on Lansat satellite images (80 m resolution). The best-documented examples have occurred in the New York Bight, where the waves were in packets and had wavelengths of 0.5 to 5 km <10, 11>. In low sea states (<2) the surface effects of internal waves may stand out from the general surface backscatter on a ship's radar screen <12>. Internal wave signatures in the Bay of Biscay and off Baja, California have also been seen in the synthetic aperture radar images from the Seasat satellite, but it is not clear that slicks are a necessary condition for the signature to be observable with this instrument.

Slicks due to Langmuir circulations and those due to internal waves should be distinguishable by the larger size scale of the latter. Langmuir circulations orient to the wind direction very quickly. There is no evidence that internal waves are dependent on wind direction and are more likely to be aligned with the bottom topography on continental shelves. The slicks associated with internal waves propagate in the direction of wave movement as new surfactant is compacted to the leading edge and material at the trailing edge dispersed. Thus a dye patch or a scattering of computer-card chips would appear to traverse the slick, whereas they would be trapped in or under the slicks due to Langmuir circulations or fronts.

2 MEASUREMENTS IN THE GULF OF CADIZ

Figure 3 illustrates the records of two continuously-measuring thermistors, at about 5 cm (SST) and 400 cm (Well) depth. These were made while SACLANTCEN's RV MARIA PAOLINA G. steamed at 10 kn northeasterly and roughly perpendicular to the local coastline south of Huelva, Spain. The sea was calm, (sea state 0-1) the sky clear, and the wind westerly at 4 to 5 m/s. The small (< 0.1°C) higher frequency variability of the upper trace was probably due to small ($\approx\pm5$ cm) excursions in depth or to contamination by aereated water of the ship's bow wave. The slow changes in temperature indicated the encounter of the western edge of a cool tongue of water at about 1350 GMT. Superimposed on this were sudden temporary temperature changes. In the 4 m depth record these spikes were always to higher temperatures and, alghough more difficult to determine, were usually negative in the shallower record. These spikes were generally associated with visually-sighted surface slicks. Exact spatial relationships were not determined but the size scales and separations are comparable in the temperature record and visual sightings.

At the end of the leg, the ship made a 270° turn and crossed its own wake (A in Fig. 3). This was to graphically illustrate the effect of turbulent stirring on the temperature records. As expected, the temperatures approached a median value. The mixing was incomplete and there was horizontal temperature structure under the wake.

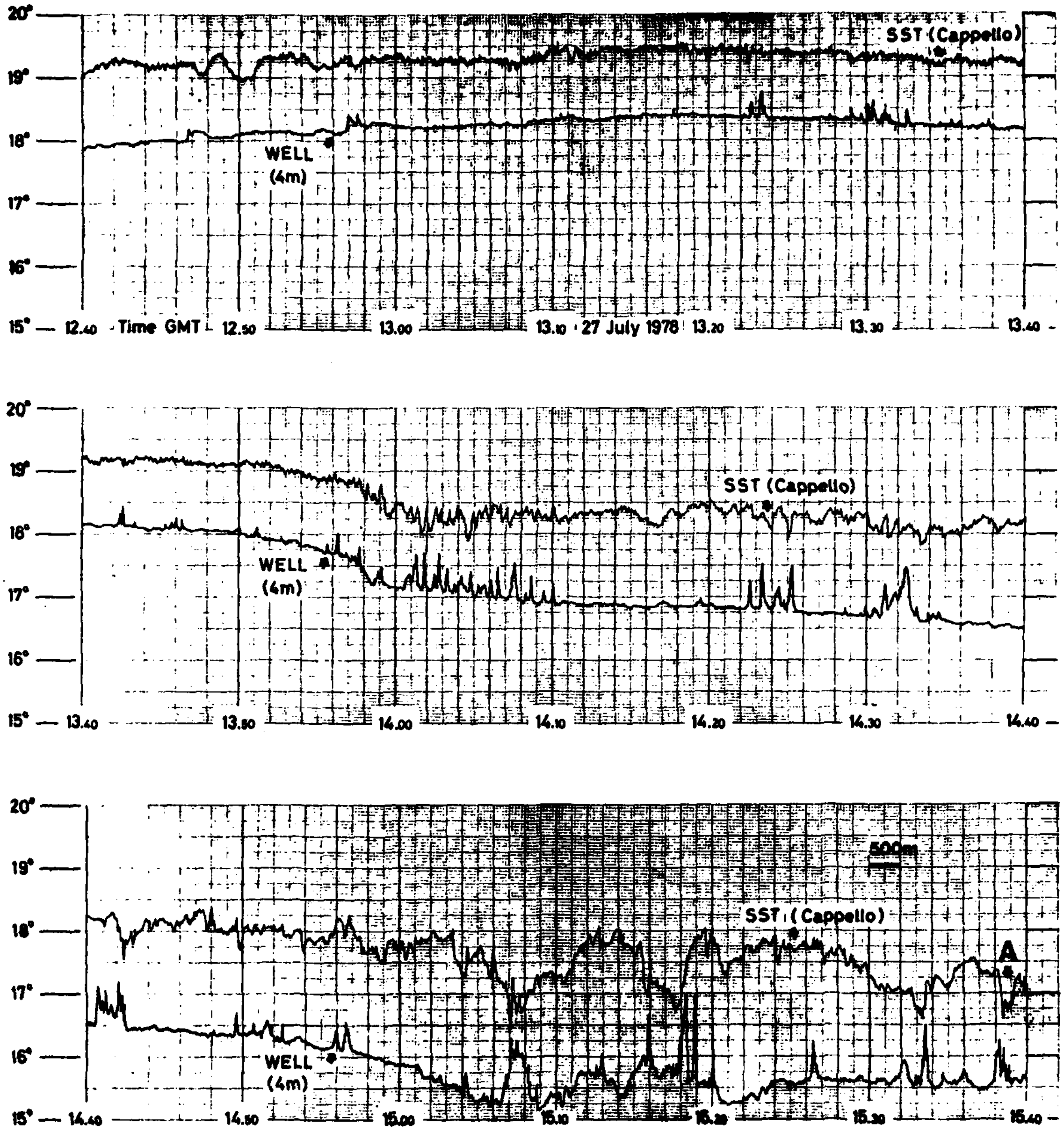

FIG. 3 ANALOGUE RECORDS OF CONTINUOUSLY IMMERSED THERMISTOR TEMPERATURE MEASUREMENTS AT ABOUT 0.05 m (cappello) AND 4 m (well) DEPTH

The time constant of the thermistors was 5 s or about 26 m at 10 kn. The slicks were estimated to be generally about 30 to 60 m wide with a much greater (> 100 m) distance between them. Assuming a symmetrical horizontal temperature distribution on each side of the axis of a slick, the thermistors would be through the maximum (or minimum) value in just over one time constant. The measured temperature changes in the deeper record were up to 1.4°C and the actual values must have been higher. Some of the slicks exhibited curvature from a generally linear axis (Fig. 4). This may be due to horizontal current shear or, assuming the slicks to be the surface signature of an internal wave, the curvature represents a deepening and shoaling of the bottom topography <11>.

From the start of the record the temperature spikes occurred in groups or packets with decreasing separations between the groups until, at the temperature drop marking the edge of the cold tongue, they were encountered continuously for 2 km.

The broad feature about 1508 GMT was associated with an indicator of a front i.e. a line of seaweed and foam along the edge of a surface slick.

The wind strength was near the threshold value for the generation of Langmuir cirulation (3 to 4 m/s) but the slicks were at a large angle to the wind. Although some of the records associated with the slicks were similar to those in the ship's wake, there were few other ships within radar range (> 70 km) and a large number of slicks. The slicks were most likely associated with internal waves. Surface effects of internal waves have been photographed in this area from satellites <13>. One hesitation in accepting the internal wave explanation is that the 4 m temperature values did not show any negative spikes as one might expect in the upwelling water in front of a wave crest. However, looking at the XBT records taken every 15 min along the track, it was noted that the gradient over a few metres below 4 m was in the region of only 0.07°C/m after 1500 GMT and much less before that time.* Thus upward flow of water would not generally show in the temperature record. There is some indication of transient lowerings in temperature after 1500 GMT.

The relationship between the positive temperature spikes at 4 m and the negative ones at 5 cm was not clear. The records are not symmetrical, there being fewer strongly negative excursions in the upper record. The thermal gradient below 5 cm was high (0.25 to 0.5°C/m over 4 m) but the upward velocity due to internal waves would have been low that close to the surface.

Depending on such factors as wind stress, heat flux (sensible, evaporative and radiative), and water density, the sea-surface temperature is often cooler than the water immediately below. The thickness of this cool skin may be only about 1 mm <14, 15>. Under a surface slick in still water the temperature will rise, due to reduced evaporation <16>. In the case of propagating slicks this effect is likely to be insignificant.

* The thermal gradients above 4 m cannot be determined from the XBT records because of the time constant of this instrument <18>.

Two factors may be involved in causing a temperature drop at 5 cm. The cooler, saltier, and thus denser water at the surface is held there by surface tension. The reduction of this by the compacted surfactants would allow the cooler water to sink. Secondly, the circulation pattern of downwelling under a slick would draw in surface water from both sides of the slick.

CONCLUSIONS

The data discussed here were part of an experiment designed to accomplish other objectives. The large number of slicks and the complexity of the temperature records were unexpected. Obviously, definitive analysis of this interesting phenomena would require a planned operation. However, certain things have become clear as a result of looking at the data and the literature.

Patterns of slicks on the sea surface can be indicative of important subsurface features. From the organization and size scale of the slicks it should be possible to identify Langmuir circulations, internal waves, or fronts. For the operational ASW ship or research vessel the clues are important. Internal waves will affect sonar performance as will a front.

Langmuir circulations may not be so important to low-frequency propagation but can be expected to deepen the mixed layer or to form a shallower one over some hours.

There will be horizontal variability in the near-surface water on the size-scale of the slicks. Temperature spikes can occur at the depth of many hull-mounted sonars (4 to 5 m). The size of these spikes will depend on the near-surface stratification. In the data discussed here, temperature jumps of 1.4°C occurred at 4 m where the temperature was on average about 2°C below that at 5 cm. This occurred under calm sea, low wind, and clear sky conditions.

Naturally-occurring slicks affect only a small proportion of the sea surface. In the data discussed, only about 6% of the temperature record at 4 m was affected by spikes. Hence a profile measured under a slick would not be a good estimate of local conditions. This may be of little importance to XBT measurements, which are anyway unreliable above 4 m in stratified conditions.

Internal waves exist in the absence of slicks but if they create slicks important features of their orientation and size-scales can be quickly determined visually.

Surface slicks have some effect on the transfer of energy between the ocean and atmosphere. They will reduce the amount of heat loss to the atmosphere by reducing evaporation and reduce the transfer of mechanical energy from the wind to the sea by preventing capillary waves. Good quantitative estimates of the importance of these effects is unavailable.

FIG. 4 VIEW ALONG THE AXIS OF A SURFACE SLICK

REFERENCES

1. EWING, G. Slicks, surface films and internal waves. Journal Marine Research 9, 3, 1950: 161-187.

2. MacINTYRE, F. The top millimeter of the ocean. Scientific American 230, 5, 1974: 62-77.

3. GARRETT, W.D. Damping of capillary waves at the air-sea interface by oceanic surface active material. Journal of Marine Research 25, 3, 1967: 279-291.

4. HORSTMANN, U., UBBRICHT, K.A., and SCHMIDT, D. Detection of eutrophication processes from air and space. In: Proc. 12th Int. Symposium on Remote Sensing of Environment, Ann Arbor, Mich, Environmental Research Institute of Michigan, 1978: 1379-1389.

5. PINGREE, R.D., HOLLINGON, P.M., and HEAD, R.N. Survival of dinoflagellate blooms in the western English Channel. Nature 265, 5591, 1977: 266-269.

6. LANGMUIR, I. Surface motion of water induced by wind. Science 87, 1938, 119-123.

7. POLLARD, R.T. Observations and models of the structure of the upper ocean. In: KRAUS E.B., ed. Modelling and Prediction of the Upper Layers of the Ocean. Pergamon Press, 1977: pp 102-117.

8. HARRIS, G.P., LOTT, J.N.A. Observations of Langmuir circulations in Lake Ontario. Limnology and Oceanography 18, 4, 1973: 584-589.

9. EWING, G. Internal Waves. In: HILL, M.N. ed. The Sea, Vol. 1, Interscience (J. Wiley and Sons), 1962: 731-751.

10. APEL, J., PRONI, J., BYRNE, H.M., and SELLERS, R.L. Near simultaneous observations of intermittent internal waves on the continental shelf from ship and spacecraft. Geophysical Research Letters 2, 1975, 4.

11. APEL, J., BYRNE, H.M., PRONI, J., and CHARNELL, R. Observations of oceanic internal and surface waves from the earth resources technology satellite. Journal of Geophysical Research 80,6, 1975: 865-881.

12. ZIEGENBEIN, J. A study of internal waves in the Strait of Gibraltar during October-November 1967. SACLANTCEN TR-127, La Spezia, Italy, SACLANT ASW Research Centre, 1968. [AD 845 865]

13. STEVENSON, R.E.. Huelva Front and Malaga, Spain, eddy chain, as defined by satellite and oceanographic data, Deutsche Hydrographische Zeitschrift, 30, 2, 1977: 51-53.

14. SAUNDERS, P.M. The temperature at the ocean-air interface. Journal Atmospheric Sciences 24, 1967: 269-273.

15. McALISTER, E.D., and McLEISH, W. Heat transfer in the top millimeter of the ocean. Journal Geophysical Research 74, 1969: 3408-3414.

16. GROSSMAN, R.L., BEAN, B.R., and MARLATT, W.E. Airborne infrared radiometer investigation of water surface temperature with and without an evaporative retarding monomolecular layer. Journal Geophysical Research 74, 10, 1969: 2471-2476.

17. POLLARD, R.T. Observations and theories of Langmuir circulations and their role in near surface mixing. In: ANGEL, M. ed. 'A Voyage of Discovery', Pergamon Press, 1977: pp 235-252.

18. WANNAMAKER, B.W. XBT measurements near the surface: some considerations SACLANTCEN SM-132. La Spezia, Italy, SACLANT ASW Research Centre, 1980.

19. CRAIK, A.D.D. and LEIBOVICH, S. A rational model for the Langmuir circulations. Journal of Fluid Mechanics 73, 1976: 401-426.

20. MOEN, J. A theoretical model for Langmuir circulations, Ph.D thesis, University of Southampton, England.